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SNODGRASS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PRELIMINARY SPECIFICATION

FOR

VEGA SPACE-VEHICLE SYSTEM

~~Available to NASA Offices and NASA Centers Only.~~

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JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California

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SECTION 3. GENERAL PROVISIONS

SECTION 1. GENERAL REQUIREMENTS

1.1 Scope.

This specification provides a general definition of the VEGA vehicle system to be used by the National Aeronautics and Space Administration in conducting various types of space flight experiments. This document describes the complete VEGA vehicle.

1.2 Complete System.

1.2.1 System Description.

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1.2.1.1 The VEGA vehicle is a three-stage rocket capable of placing payloads up tc approximately 5000 pounds into orbit, or sending approximately 600 pounds of payload on an escape mission. The first stage is a modified Series D ATLAS. The second stage is composed of a General Electric 405-H 2 engine and tanks fabricated on standard ATLAS tooling. The third stage – when used – is powered by a JPL-developed, 6000-pound-thrust N_2O_4 - N_2H_4 propulsion system. The payload compartment is mounted on top of the third stage.

1.2.1.2 The VEGA is guided to the proper injection conditions by an ICBM-type radio-guidance system mounted in the second stage and a simple inertial system in the third stage. Such instrumentation, support, and test equipment as are necessary to test and fire the VEGA and evaluate the flight performance are to be provided. telem ? ?

inertial [illegible] guidance [illegible] (150-220 lb w.o. [illegible])
GE radio inertial (220 lbs w.o. antenna)
auto pilot - programmer [illegible]

1.2.2 Mission Capabilities.

1.2.2.1 General. The VEGA vehicle will be capable of carrying a sufficient payload into orbit or to escape velocities such that experiments in the development of space flight equipment or involving determination of space, lunar, and planetary conditions can be conducted.

1.2.2.2 Specific. The initial flight experiments will be planned to prove the design of the vehicle and associated equipment by relatively simple satellite and space probe missions. Scientific measurements will be of secondary importance during the initial phase. how many vehicles?

1.2.2.3 Satellite. The VEGA vehicle will be used to conduct a variety of satellite experiments requiring reasonably precise orbits at high and low altitudes, inclinations, and ellipticity. Although initial flights will be from the Atlantic Missile Range, later experiments may be flown from the Pacific Missile Range or an equatorial site.

1.2.2.4 Lunar. The VEGA vehicle will be capable of performing such missions as lunar satellite, lunar landings, and circumlunar flights carrying sufficient payload to conduct useful scientific and technological experiments.

1.2.2.5 Deep Space. Deep space missions, such as Mars and Venus probes, will be performed with the VEGA vehicle. In addition, experiments in the development of space navigation, communication systems, and flight-path correction systems will be conducted.

cannot count on separate launch site — heavy political involvement

1.2.3 Operational Requirements.

1.2.3.1 Sites. The VEGA vehicle, its ground support system, and the instrumentation, tracking, and guidance equipment shall be designed so that operation from equatorial sites will be possible without major revisions in design. Where special features are required for equatorial firing operations, these will be incorporated, but not in such a way as to interfere with the attainment of the specified schedule of firings from the Atlantic Missile Range or the Pacific Missile Range. ?

1.2.3.2 Transportability. All elements of the vehicle and all ground equipment shall be as mobile as practical, and, if possible, shall be packaged for transport to survive the same environments as those specified for the ATLAS in this application. Separate transport of the vehicle stages is acceptable.

1.2.3.3 Launching Environment.

1.2.3.3.1 Weather. The vehicle and associated systems must be capable of launching with a high probability at a given time. Therefore, the wind and weather conditions cannot be restrictive; a successful launching must be possible under all reasonable weather conditions expected for the given site and date. Extreme conditions, such as hurricanes and tornadoes, are excluded. at PMR also? (est. 10% of time)

70% Fla. E

1.2.3.3.2 Protective Equipment. During preparations for firing, all systems must withstand the local environment, not requiring humidity or air-temperature control except as applied to internal or special equipment. Sun shades and rain shelters are permissible. All equipment shall be designed for reliable and consistent operation within specification tolerances over an ambient air temperature range of +25 to +110°F, with relative humidity up to 100 per cent. All equipment shall be capable of storage, preparation, and alert-holding times compatible with those required for the ATLAS booster in this application.

1.2.3.4 Firing Constraints. The missions required of this vehicle include lunar and interplanetary experiments which are restricted to limited firing times of a few hours or minutes on each of several successive days. All systems must accommodate this constraint. In the event that a firing time is missed, it must be possible, without damage or degradation of the equipment, to cancel and reschedule for the following day. Unloading and reloading of propellants, disarming and rearming of safety and explosive devices, resetting of control parameters, and all other such operations as necessary, must be possible during a period which varies with the mission, but is generally close to 24 hours. On interplanetary missions where two vehicles are prepared for nearly simultaneous launching, this requirement may be met if desired by exchanging the ready status between the two launchers, so that, effectively, a firing cancellation and reschedule time of nearly 48 hours can be made available. During the firing intervals, and between successive intervals as defined above, all equipment must be capable of accepting the varying parameter inputs occasioned by the motion of the earth and other bodies, and of translating these inputs into the required conditions for successful completion of the launching, propulsion, guidance, tracking, telemetering, range-safety, and payload experiment phases of the operation.

1.2.3.5 Overall Reliability. The complete system shall be designed to yield the highest probability of success for a given experiment, and shall be designed to achieve this probability of success during each successive astronomically-available launch time. For the purpose of this specification, the probability of success for the vehicle system shall be defined as the probability of injecting the payload into the prescribed orbit within the coordinate tolerances specified for the particular mission.

1.2.4 Guidance Requirements.

1.2.4.1 General. The guidance system for the VEGA vehicle shall consist of three major parts:

(1) The ground-complex portion of an existing ICBM radio-guidance system, to be located at the launch site.

(2) The vehicle-borne portion of the ICBM radio-guidance system, to be carried in the second stage. 7

(3) A simple, lightweight, body-fixed inertial guidance system to be carried in the third stage.

1.2.4.2 Radio Guidance. The radio-guidance system will provide for staging, path correction, and shutoff signals, as required for the first and second stages. The system will provide steering commands for the autopilot systems of the first and second stages. If reasonably accurate (±30 ft/sec) cutoff for the GE 405-H engine is not available, the ground equipment of the radio-guidance system will be required to compute and transmit initial condition corrections to the third-stage guidance system before third-stage separation.

1.2.4.3 Inertial System. The third-stage guidance system will utilize the programmer and autopilot of that stage for directional control, and the integrated output of an accelerometer mounted along the thrust axis for speed control. In addition, an accurate attitude-reference gyro may be required in the second stage. The third-stage guidance system will use initial conditions determined prior to launch, if reasonably accurate cutoff for the GE 405-H engine is available; if not, the system requires that initial condition corrections be computed and transmitted from the radio-guidance system.

1.2.5. System Integration

1.2.5.1 General. The design and operational requirements of each of the major elements of the VEGA vehicle shall be co-ordinated in such a manner as to satisfy the overall system objectives of performance, reliability, and safety.

1.2.5.2 Cabling. Electrical connections between the various elements of the vehicle and the ground launch and check-out equipment shall be arranged so that it is possible to adequately test the performance of the individual elements and interstage connections required for successful flight operation.

1.2.5.3 <u>Firing Preparations</u>. The system shall be designed so that the fueling, pressurization, and checkout operations required for launching can be conducted as independently as possible without decreasing system reliability.

SECTION 2. TECHNICAL REQUIREMENTS

2.1 First Stage.

2.1.1 Propulsion.

2.1.1.1 General. The first-stage propulsion system will be that defined by the pertinent Series D ATLAS specifications.

2.1.1.2 Modifications. It is recognized that the ATLAS propulsion system is designed and fabricated to satisfy the requirements of an ICBM weapon system. For the utilization of this basic propulsion system in space research vehicles, some of the military constraints on design requirements may not be applicable, and modifications resulting in improved performance, including reliability, may be desirable.

2.1.2 Structure. The structure of the ATLAS, as modified for use in the VEGA vehicle, shall not retrofit be designed to meet all pertinent ATLAS specifications, plus appropriate portions of the specifications applicable to the CENTAUR vehicle. Structural design criteria, basic load analyses, and stress and strain analyses shall be obtained for all conditions applicable to VEGA missions. The basic structure shall be modified as necessary to meet all critical conditions so derived. Weight control, quality control, inspection and access, environmental protection, proof testing, and field handling of the structure shall conform to ATLAS standards, where applicable.

2.1.3 Autopilot and Control. An autopilot and control system shall be provided in the first stage for roll, pitch, and yaw control of the three-stage vehicle. The autopilot system shall consist of single-degree-of-freedom integrating rate gyros and rate gyros stabilizing the airframe. Control of the vehicle may be effected by swiveling the rocket motors, small jets, or turbine exhaust, with preference for the standard ATLAS system. The autopilot shall be capable of overcoming all known sources of torque on the airframe, such as winds, fuel slosh, aerodynamics, airframe bending, and rocket motor misalignment. If desired, common usage of some portions of the autopilot and control system may be employed by all stages. The autopilot shall be capable of accepting steering commands from an ICBM-type radio-guidance system located in the second stage of the vehicle.

2.1.4 Separation. The first stage shall be equipped with all necessary devices to obtain reliable and reproducible behavior upon separation of the second stage. Separation of the ATLAS engines, as used in the ICBM mission, will be required on the VEGA vehicle.

2.1.5 Instrumentation.

2.1.5.1 Telemetering.

2.1.5.1.1. Airborne telemetering equipment shall be installed in the first stage to accomplish the following objectives:

(1) Evaluate propulsion.

(2) Evaluate guidance and control performance.

(3) Obtain environmental information during flight.

(4) Evaluate separation.

(5) Monitor range-safety destruct events and operations.

(6) Make such other measurements during flight as are deemed necessary.

2.1.5.1.2. In general, power for airborne instrumentation shall be supplied from a source other than the main APU.

2.1.5.1.3. Suitable test consoles and checkout equipment shall be provided as necessary to perform tests on the telemetry equipment, both before installation and after installation on the airframe, and during all checkouts thereafter until the missile is fired. This equipment shall include provision for obtaining permanent telemetry recordings during important tests, for evaluation of the missile test performance.

2.1.5.1.4. Suitable receiving and recording equipment shall be installed and operated at the launching site and at other locations as required on the range complex to receive and record telemetry data throughout the powered flight of the first stage, or longer if information of interest is available. The launch station shall provide quick-look data as required.

2.1.5.1.5. Suitable quantitative data reduction will be provided to allow each responsible agency to determine missile performance and to detect and evaluate equipment or component failures after the flight. A complete set of calibration records for the airborne system must be maintained.

2.1.5.2 Range Safety. Range-safety airborne equipment shall be provided as necessary to meet the requirements of the range. Associated ground equipment to perform the range-safety function shall also be provided, including checkout consoles, interrogation transmitter, and any other necessary equipment. Recording of ground range-safety events shall be provided.

2.1.5.3 <u>Other Instrumentation</u>. Any other instrumentation necessary to determine stage performance, except telemetering, shall be provided, including camera coverage, DOVAP, etc. Raw data shall be suitably reduced for flight analysis purposes.

2.1.6 <u>Power</u>. An APU system shall be provided in the first stage to supply power for all electrical and control requirements of the first stage. Wherever possible, a common power unit shall be provided instead of several smaller units. If desired a common APU may be provided in the second stage to supply the needs of both stages. ?

2.2 <u>Second Stage</u>.

2.2.1 <u>Propulsion</u>.

2.2.1.1 <u>General</u>. The second-stage propulsion system will consist of a General Electric 405-H2 engine, in accordance with the pertinent specifications, and propellant tanks and pressurization system as described in specifications to be provided.

2.2.1.2 <u>Specific.</u>

2.2.1.2.1. The propulsion system shall be capable of satisfactory operation with various total propellant weights, as defined by the payload and mission requirements and the ATLAS structural limitations.

2.2.1.2.2. Re-start capability shall ~~not~~ be provided.

2.2.1.2.3. Shutoff capability of the second stage, as necessary to satisfy the requirements of the vehicle guidance system, shall be provided.

2.2.1.2.4. Such component heaters, vents, and relief valves as required shall be provided to insure system firing readiness after the maximum delay time permissible for the ATLAS booster stage.

2.2.2 Structure. The structure of the second stage shall be designed to the same criteria as those for the first stage, plus additional criteria peculiar to the second-stage handling and flight. The structure shall mate interchangeably with both first and third stages and shall accept a range of loadings consistent with the weights and trajectories used on the various VEGA missions. The structure shall provide mountings for the guidance equipment described in other sections of this specification. Access to the second-stage engine and guidance equipment shall be available when the vehicle is completely assembled on the launcher and also when the second stage is separated from the other stages.

2.2.3 Autopilot and Control. An autopilot and control system shall be provided in the second stage to control the attitude of the mated second and third stages. The autopilot system shall consist of single-degree-of-freedom integrating rate gyros and rate gyros stabilizing the airframe. Control may be effected by swiveling the rocket motor, small jets, or the turbine exhaust. The autopilot shall be capable of overcoming all known sources of torque on the airframe, such as winds, fuel slosh, aerodynamics, airframe bending, and rocket motor misalignment. If desired, common usage of some portions of the autopilot and control system may be employed by all stages. The autopilot shall be capable of accepting steering commands from an ICBM-type radio-guidance system located in the second stage. Provision shall be made for mounting and integration of the airborne portions of the radio-guidance system. The attitude deviation at the end of burning of the second stage shall be less than ±2 milliradians in pitch and yaw, and ±1 degree in roll.

So open

2.2.4 Separation. The second stage shall be designed, equipped, and instrumented for reliable, reproducible separation and ignition. The achievement of this condition shall be demonstrated by analysis and tests to the maximum extent reasonable before flight.

2.2.5 Instrumentation. The provisions of Section 2.1.5 of this specification shall also apply to the second-stage instrumentation.

2.2.6 Power. An APU system shall be provided in the second stage to supply power for all electrical and control requirements of the second stage. Wherever possible, a common power unit shall be provided instead of several smaller units. Power shall be provided for the airborne portions of the radio-guidance systems.

2.3 Third Stage.

2.3.1 Propulsion.

2.3.1.1 General. The third-stage propulsion system shall consist of a regeneratively cooled rocket engine supplied with N_2O_4 and N_2H_4 by a pressurized helium pumping system.

2.3.1.2 Characteristics. The propulsion system shall have the following nominal characteristics:

Vacuum thrust, F_{∞} = 6000 lbs

Vacuum specific impulse, $I_{SP_{\infty}}$ = 300 sec

Characteristic Velocity, C^{*} = 5600 fps

Mixture ratio, r = 1.0

Chamber pressure, P_c = 150 psia

Expansion ratio, ϵ = 20.0

2.3.1.3 Storage. The system shall be capable of storage in a ready-to-fire state, except for pressurization, for a period of at least one month.

2.3.1.4 Coasting. Although a positive acceleration is required for satisfactory starting, coasting with zero acceleration after second-stage burnout shall be permissible.

2.3.1.5 Shutoff. Thrust termination on command from the guidance system shall be possible. The velocity error resulting from shutoff shall be within the limits defined by the guidance system requirements.

2.3.2 Structure. The structure of the third stage shall be designed to criteria consistent with those applied to the first and second stages, plus criteria peculiar to third-stage handling and flight.

2.3.2.1 Tanks. The propellant tanks shall be constructed from 2014-T6 aluminum alloy and shall be designed to a nominal yield safety factor of 1.0. The pressurizing-gas tanks shall be made from 6 Al-4V titanium alloy and shall be designed to an ultimate safety factor of 1.3. Structural analysis and tests will be made to assure conformity to tank specifications.

2.3.2.2 Intertank and Aft Structure. The intertank and aft structures shall be semimonocoque shells made from aluminum and magnesium alloys.

2.3.2.3 Guidance Compartment. The third-stage structure shall include a compartment suitable to contain the injection guidance system.

2.3.2.4 Payload Attachments. The third-stage structure shall be designed to support and accommodate all payloads specified for the VEGA vehicle.

2.3.3 Autopilot and Control. An autopilot and control system shall be provided for roll, pitch, and yaw control of the third stage and the payload. The attitude shall be measured by single-degree-of-freedom integrating rate gyros, and rates shall be measured by rate gyros or networks. Control may be effected by swiveling the rocket motor or small jets. The autopilot shall be capable of overcoming all known sources of torque on the airframe, such as winds, fuel slosh, aerodynamics, airframe bending, and rocket motor misalignment. If desired, common usage of some portions of the autopilot and control system may be employed by all stages. For some missions, attitude control of the last stage during coasting flight will be required, necessitating provisions for control without the use of the gimbaled rocket thrust chamber. Attitude at the end of burning of the third stage shall be controlled to within ±5 milliradians of the desired orientation.

2.3.4 Separation. The third stage shall be designed either (1) to ignite and separate immediately upon shutdown of the second stage, or (2) to separate and coast as long as necessary before ignition. During this coasting period, the attitude of the stage shall be controlled to be within required tolerances at engine ignition, and devices shall be supplied to assure successful ignition after the coast period.

2.3.5 Instrumentation. The provisions of Section 2.1.5 of this specification shall also apply to the third-stage instrumentation, except that no range-safety equipment will be carried in the third stage.

2.3.6 Power. An APU system shall be provided in the third stage to supply all electrical and control requirements of the third stage. For some missions, a coasting period between second-stage cutoff and third-stage ignition will require provision of attitude control for long periods of time, thus necessitating a very efficient power supply.

2.4 Payload Compartment

The payload compartment and its attachments shall be designed to mate with the third stage and to accept the loads and environments characteristic of the particular mission. In the event that a separate shroud, or aerodynamic protective cover, is used and is jettisoned during flight, the design requirements on this shroud shall be compatible with the requirements on the rest of the vehicle structure.

2.5 Ground Support Equipment

2.5.1 Fueling. Equipment for loading, unloading, and reloading of propellants and other fluids in all stages must be supplied and shall perform reliably and accurately. Fill times and other aspects of the prefiring countdown shall be compatible with ATLAS specifications and practice to the extent practical for this application.

2.5.2 Checkout. Equipment shall be supplied that can determine the functional condition of all operating systems in the vehicle and in the ground equipment. The quantity of checkout equipment shall be such as to support the required firing rate with a reasonable allowance for availability of spares.

2.5.3 Launching Facilities. Existing, modified, or new launching facilities must conform to the specified missions of the VEGA vehicle and must incorporate provisions for:

(1) Vehicle checkout in a protected area.

(2) Stage erection and assembly on launcher.

(3) Fueling.

(4) Firing.

SECTION 3. GENERAL PROVISIONS

3.1 Competing Characteristics.

Where competing criteria exist in the design of the system, they shall be given preference in the following order:

(1) Personnel safety.

1 (2) In-flight and launch-on-time reliability.

4 (3) Payload capability.

2 (4) ~~Schedule.~~ Early availability

3 (5) Accuracy.

6 (6) Growth potential.

5 (7) Compatibility with other programs.

3.2 Environments.

This system is most likely to be operated in low latitudes and, therefore, hot and humid rather than cold and dry environments should be emphasized in its design.

3.2.1 Temperature Limits.

(1) Storage of empty vehicle, +20 to +130°F

(2) Storage of vehicle after filling tanks, +25 to +110°F

(3) Firing, ambient air +25 to +110°F, with local equipment temperatures controlled more closely, if required

3.2.2 Time and Humidity.

(1) Empty vehicle, 6 months at 80°F, and 40% relative humidity

(2) On pad, filled except for lox, 2 weeks at temperature listed above, and 80% relative humidity.

3.3 Reliability Testing and Quality Control.

3.3.1 Inspection. Inspection shall be conducted throughout the fabrication and assembly of the vehicle system in accordance with the highest quality-assurance standards employed in missile construction. Inspected equipment shall be so marked.

3.3.2 Environmental Specifications. The environmental conditions associated with the vehicle stages and payload shall be determined and detailed specifications established covering the essential characteristics.

3.3.3 Environmental Type-Approval Testing. Equipment environmental specifications shall be established, based on the best available data. The mean-extreme environment shall be determined and specified. Sample models of all equipments shall be subjected to type-approval environments and their successful performance shall be adequately demonstrated. An appropriate number of such units shall be so tested and marked, and thereafter shall be considered expended and unusable. This procedure shall establish the equipment design as approved for flight use.

3.3.4 System Testing. Specifications shall be established for testing every conceivable and reasonable feature of the system when the vehicle is in a completely assembled state. The overall system test of the completely assembled vehicle shall be successfully conducted before the vehicle is shipped to the range. This overall system test shall be successfully repeated at the range assembly building before the missile is moved to the firing pad.

3.4 Documentation.

The following documentation shall be prepared and maintained as required to define completely the VEGA system:

(1) Drawings and specifications

(2) Procedures and firing instructions

(3) Engineering reports

(4) Inspection and quality control reports

(5) Test reports

(6) Flight reports and flight data

(7) Complete historical record describing each vehicle

3.5 Performance Factors Control.

In order that the payload weight can be properly matched to the vehicle for each specific flight mission at the earliest practical date, adequate controls and records shall be maintained on all factors affecting vehicle payload capability. Included in these factors are such items as complete detailed weight breakdowns, rocket engine performance, propellant outages, residuals, and detailed flight histories.